Variable Field Module Allows Study of Samples Under Either In-Plane or Out-of-Plane Magnetic Fields

Introduction

The Variable Field Module (VFM4) is an accessory for Asylum Research MFP-3D atomic force microscopes (AFMs) that enables researchers to apply an adjustable magnetic field either in-plane with the sample or out-of-plane while simultaneously making AFM measurements (Figure 1). Though most often used in conjunction with magnetic force microscopy (MFM), the VFM4 is also used with techniques like conductive AFM (CAFM) and on diverse samples including piezoelectric and ferroelectric materials. No other commercial solution offers the same capabilities, versatility, and ease of use for magnetics research.

Figure 1: VFM4 Variable Field Module
The VFM4 is a small stage that easily mounts to the MFP-3D scanner. The photo shows it in the in-plane field configuration.

Applying In-Plane Magnetic Fields

Figure 2 shows a diagram of the VFM4 configured for in-plane magnetic fields. For highest field strength (up to ±8000 G) and best field uniformity, small, thin samples are used and placed directly between the two removable pole pieces.

Figure 3 demonstrates the effect of an increasing magnetic field on bits written to a piece of PMR (perpendicular magnetic recording) hard disk. The bits are progressively degaussed as the in-plane magnetic field is increased from zero to >7000 G.

Figure 4 presents MFM phase images of a Terfenol-D disk during and after application of in-plane fields applied perpendicular to the direction of magnetization in the film.

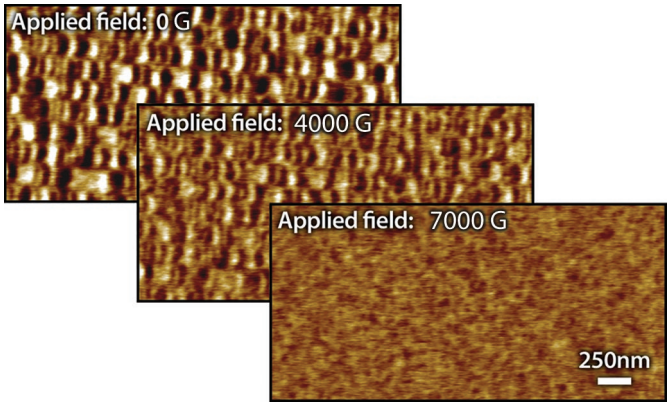

Figure 3: Degaussing bits on PMR hard drive
Three MFM images showing a piece of PMR hard disk that is eventually degaussed when the in-plane magnetic field reaches 7000 G.

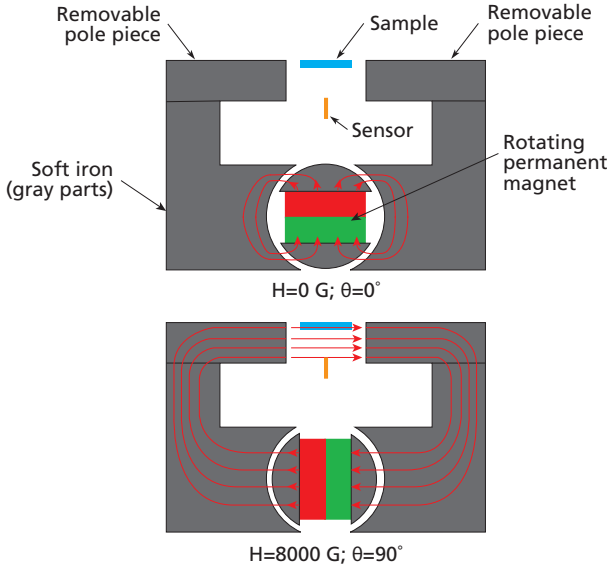

Figure 2: Schematic of in-plane field configuration
The strength and sign of the magnetic field applied to the sample depends on the rotation angle (θ) of the rare earth magnet. At 0° or 180°, the magnetic flux is shunted away from the sample by the soft iron armature and pole pieces. As the magnet rotates, more and more flux is coupled instead through the sample. At 90°, the field is maximized.

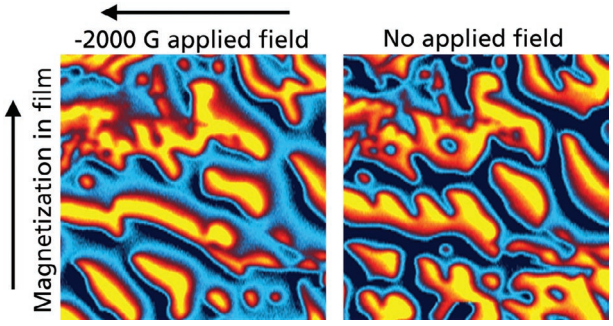

Figure 4: Effect of in-plane field on Terfenol-D film
MFM phase images of the Terfenol-D disk, 10 µm scans. (left) Imaged while under a -2000 G field, and (right) after field removal. Image courtesy of S. Xie, Xiangtan Univ. and J. Li, Univ. Washington.

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Applying Out-of-Plane Magnetic Fields

Figure 5 shows how the removable pole pieces of the VFM4 allow it to be reconfigured for out-of-plane magnetic fields. The flux lines are sketched in an idealized way here, but in reality, the longer, less direct path necessitated by placement of the AFM head above the sample reduces the maximum achievable field to about ±1200 G.

Figure 6 shows one example from a separate Application Note, "Magnetic Force Microscopy Under Applied Perpendicular Fields with Asylum Research AFMs," which can be found on our website at: http://AFM.oxinst.com/OOP-MFM

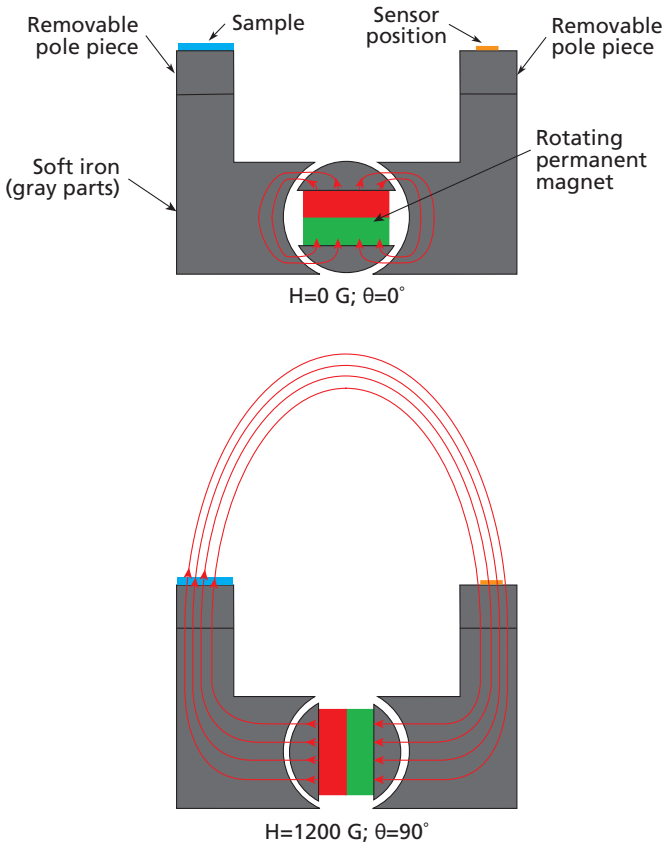

Figure 5: Schematic of out-of-plane field configuration
The out-of-plane configuration works with the same principles as the in-plane configuration, except that the sample is placed on one pole of the iron armature, well-separated from the other pole, such that the flux lines run through the plane of the sample. Both configurations place the sensor at a position symmetric in the field relative to the sample to avoid a positional offset error and to achieve better accuracy.

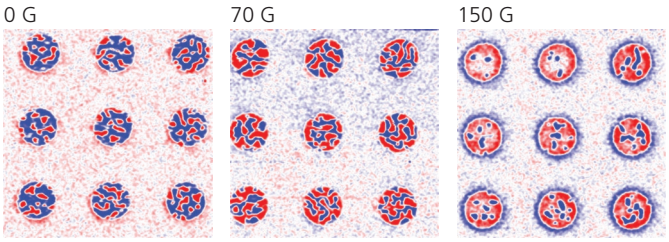

Figure 6: Magnetic skyrmions in Co-based thin film pads
Imaged with MFM under out-of-plane magnetic fields. Each pad is ~900 nm in diameter. Images courtesy of K. Bouzehouane, Unité Mixte de Physique CNRS, Thales, Univ. Paris-Sud, Université Paris-Saclay, France.

Features and Benefits

- Easily configurable for applying both in-plane and out-of-plane magnetic fields
- Unique design uses a permanent magnet, eliminating the large thermal drift caused by field generators that use electromagnets.
- Field strength adjustment is motorized and can be controlled using linear ramps.
- Integrated Hall sensor measures the in-plane field strength, while an external Gaussmeter is provided for measuring the out-of-plane field strength.
- Optional kit allows application of a high-voltage tip bias (adjustable, ±150 V for MFP-3D Infinity or ±220 V for MFP-3D Origin+).

VFM4 Specifications

- Field directions: Includes both in-plane and out-of-plane capabilities, easily reconfigured by the user
- Maximum field: ±8000 G in-plane
- Maximum field ±1200 G out-of-plane (±1500 G typ.)
- Environmental controls: Ambient only (no heating, cooling, or closed cell available concurrent with VFM)

Think the VFM4 might be helpful to your research? Let's talk!

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